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Postbreeding Movements of the Dark Gopher Frog, *Rana sevosa* Goin and Netting: Implications for Conservation and Management

STEPHEN C. RICHTER,[1,2] JEANNE E. YOUNG,[1,3] RICHARD A. SEIGEL,[1] AND GLEN N. JOHNSON[4]

[1]*Department of Biological Sciences, Southeastern Louisiana University, SLU 10736, Hammond, Louisiana 70403-0736, USA*
[4]*USDA Forest Service, Southern Research Station, Southern Institute of Forest Genetics, 23332 Highway 67, Saucier, Mississippi 39574, USA*

ABSTRACT.—**Conservation plans for amphibians often focus on activities at the breeding site, but for species that use terrestrial habitats for much of the year, an understanding of nonbreeding habitat use is also essential. We used radio telemetry to study the postbreeding movements of individuals of the only known population of dark gopher frogs, *Rana sevosa*, during two breeding seasons (1994 and 1996). Movements away from the pond were relatively short (< 300 m) and usually occurred within a two-day period after frogs initially exited the breeding pond. However, dispersal distances for some individuals may have been constrained by a recent clearcut on adjacent private property. Final recorded locations for all individuals were underground retreats associated with stump holes, root mounds of fallen trees, or mammal burrows in surrounding upland areas. When implementing a conservation plan for *Rana sevosa* and other amphibians with similar habitat utilization patterns, we recommend that a terrestrial buffer zone of protection include the aquatic breeding site and adjacent nonbreeding season habitat. When the habitat is fragmented, the buffer zone should include additional habitat to lessen edge effects and provide connectivity between critical habitats. For our study site, we recommend a 1000-m buffer zone around the primary breeding site and each of two other potential breeding ponds.**

For amphibians that breed in temporary ponds, the hibernation sites, breeding sites, and foraging areas may be temporally and spatially separated, and individuals must migrate to and from these sites in seasonal cycles (Semlitsch, 1981; Sinsch, 1990). Because individuals are generally concentrated only during the breeding season, many studies of amphibian biology take place in and adjacent to breeding sites and not in the nonbreeding habitats. However, designing a comprehensive management plan for any amphibian that uses terrestrial habitats for much of the year requires an understanding of habitat use during both breeding and nonbreeding seasons (Dodd, 1996; Dodd and Cade, 1998).

Postbreeding movements of amphibians into adjacent terrestrial habitats are poorly understood, and distances that most species normally disperse are unknown (Dodd, 1996; Dodd and Cade, 1998). Although mark-recapture studies have provided valuable data on dispersal distances, recent advances in radio-telemetric methods make this a more suitable method for studying postbreeding movement patterns and habitat selection. Although these data are critical in understanding habitat use by frogs, few telemetry data are yet published. One study of ranid frogs (*Rana clamitans*) using terrestrial habitats showed a maximal dispersal distance of 560 m, although there was considerable inter-individual variation (Lamoureux and Madison, 1999).

Gopher frogs are rare and poorly studied frogs whose geographic range once extended throughout the southeastern coastal plain from North Carolina to Louisiana. Although once common to abundant in coastal Mississippi and Louisiana (Allen, 1932; Dundee and Rossman, 1989), breeding populations of gopher frogs west of Alabama have been severely reduced in numbers. They are thought to be extirpated in Louisiana and are now known to occur only at a single location in the De Soto National Forest in Harrison County, Mississippi. A recent study by Young and Crother (2001) indicated that this population is genetically distinct from other populations of gopher frogs and that it should be recognized as *Rana sevosa* Goin and Netting. Thus, there is a vital need for information on both breeding and postbreeding activities.

Because gopher frogs are secretive and difficult to locate outside of the breeding season, knowledge of their ecology is generally limited to studies of reproductive ecology at breeding

[2] Corresponding Author. Present Address: Department of Zoology, University of Oklahoma, Norman, Oklahoma 73019, USA; E-mail: richter@ou.edu.
[3] Present Address: Applied Ecology Research Group, University of Canberra, Australian Capital Territory 2601, Australia.

sites (e.g., Bailey, 1991; Semlitsch et al., 1995; Young, 1997; Palis, 1998; Richter, 1998). During the nonbreeding season, gopher frogs have been reported to take shelter in the burrows of gopher tortoises, *Gopherus polyphemus* (Franz, 1986). Distances moved from the breeding site after reproduction are unknown, except for two individuals in Florida that were found 1.6 and 2.0 km from a breeding site (Carr, 1940; Franz et al., 1988). The absence of quantified data addressing postbreeding movement patterns makes it difficult to design and assess an appropriate conservation plan for this species. In this study, we used radio telemetry to determine postbreeding movement patterns of *R. sevosa* at its Mississippi breeding site and make specific management recommendations.

Materials and Methods

Study Site.—All work was performed at Glen's Pond and its surroundings, located in the De Soto National Forest in Harrison County, in southern Mississippi. Glen's Pond is an upland, winter-filling, ephemeral pond with an open canopy located in a primarily longleaf pine (*Pinus palustris*) ecosystem. Although most of the surrounding habitat is part of the De Soto National Forest, the land approximately 200 m north of Glen's Pond was managed by International Paper Company (IP) as a pine plantation until 1999, when it was acquired by a private company for residential development.

Radio Telemetry.—Frogs used for radio telemetry were captured during postbreeding migrations by hand or by drift fence with 25-liter pitfall traps (Gibbons and Semlitsch, 1981). All frogs were measured (snout–vent length; SVL) to the nearest millimeter, weighed to the nearest 0.5 g with a Pesola® spring balance, given an individual toe clip following the scheme of Donnelly (1989), fitted with transmitters, and released at the site of capture within 24 h. Males were distinguished from females by their thumbs, which enlarge during the breeding season, and by the paired lateral vocal sacs.

Transmitters were attached to frogs by using a small piece of polyethylene microcatheter tubing and a barb from a large flyline eyelet to make a harness (Bartelt and Peterson, 2000). The tubing was threaded through a prefabricated hole in the transmitter, and the free ends of the tubing were connected with the barb. The harness was positioned on the waist of the frog by sliding it over the extended hind legs. The fit of the harness was snug over the thighs and slightly looser around the waist. We used external transmitters (Holohil Systems Inc., Canada) with a battery life of approximately 70 days and a weight of 1.44 g. Harnesses weighed less than 0.001 g, and the percent of body weight for the harness plus transmitter for all individuals was 3–5% of the total mass of the frog. This is well below the general rule of 10% as the maximum weight ratio of transmitter packages to body mass (Richards et al., 1994).

To determine potential negative effects on gopher frogs, the harness design was tested on southern leopard frogs, *Rana sphenocephala*, in the laboratory for 60 days. No skin abrasions or other problems were observed, and frogs continued to eat normally. The steel barb used to hold the tubing together was susceptible to moist conditions and would, over time, deteriorate and allow the harness to be lost.

With few exceptions, frogs were relocated daily. For each sighting, we recorded date, time, general habitat, and any behavioral observations. Care was taken to avoid disturbing the frogs. Each relocation site was marked with plastic flagging, and the distance to the last sighting was measured with a measuring wheel or hipchain. Directions of these positions relative to one another and to the center of the pond were obtained by compass; the coordinates of the final locations were determined with a Global Positioning System unit (TrimbleNavigation NavBeacon XL®; 1-m accuracy). Migration distances were measured from the center of the pond to determine the area used by the population after breeding.

Statistics.—Statistical tests were performed using SYSTAT 7.0 (SPSS, Inc.). Means are followed by $\pm$ 1 SE. Alpha was 0.05.

Results

General Movement Patterns.—Fourteen frogs (nine males and five females) were equipped with radio transmitters. Two frogs subsequently lost their transmitters prior to movement from the pond, resulting in a total of 12 radio-telemetered gopher frogs (seven males and five females). Although the study spanned two separate breeding seasons (1994 and 1996), no individual frog was tracked both years (Table 1). Frogs were followed for 24–88 days (mean = 52 days) from 5 February to 25 May 1994 or from 29 February to 6 June 1996 (Table 1).

All frogs moved relatively short distances (< 300 m) from the pond and changed location infrequently (Table 1; Fig. 1). All initial movements occurred < 24 h following release. Mean distance moved from the center of the pond was 173.0 $\pm$ 23.43 m (range 49–299 m). The known (= minimum) number of movements (changes in location) recorded per frog ranged from 1–5 (mean = 2.3 $\pm$ 0.43; Table 1), and most movements were associated with rainfall events (65% in 1994; 100% in 1996; Fig. 2). During migration, five individuals used clumps of grass for refuge; one was found buried approximately 15 cm un-

TABLE 1. Total movement distance and measurement data for all frogs monitored through radio telemetry in the 1994 and 1996 breeding seasons.

Frog	Sex	Mass (g)	SVL (mm)	No. of moves	Distance from pond center (m)	Tracking period (d)	Dates monitored
1	♂	50.0	72.0	1	206	35	11 Mar–15 Apr 94
2	♂	51.5	74.0	2	130	24	13 Mar–5 Apr 94
3	♂	41.5	72.0	5	170	52	13 Mar–3 May 94
4	♀	53.0	78.0	1	49	45	13 Mar–26 Apr 94
5	♂	35.0	69.0	2	49	53	13 Mar–3 May 94
6	♀	46.5	82.0	2	203	75	13 Mar–25 May 94
7	♂	39.5	70.0	4	268	88	5 Feb–3 May 94
8	♂	51.0	79.0	3	82	34	1 Apr–4 May 96
9	♀	46.0	91.0	1	191	38	13 Apr–20 May 96
10	♀	60.5	94.0	3	299	63	18 Mar–19 May 96
11	♂	43.5	81.0	2	236	26	7 Mar–1 Apr 96
		40.0	81.0	2	236	43	13 Apr–26 June 96
12	♀	38.5	77.0	1	193	47	18 Mar–2 May 96

der leaf litter. However, final recorded locations for all individuals were underground retreats associated with stump holes, root mounds of fallen trees, or small mammal burrows.

Two individuals (#4 and #5 in Table 1) in 1994 remained within the area of the dried pond (49 m from the pond center), and in 1996, one frog (#8) remained within the area of the complete drift fence (82 m from the pond center) but not within the actual pond area (Fig. 1). The final positions of all other individuals were beyond the drift-fenced area. Of these, four moved to the north, three to the south, and two to the west (Fig. 1).

The skeleton of one frog (#12) was found 44 days following initial release. Cause of death is unknown, but its burrow was submerged by heavy rain three times following the frog's retreat underground. After the water receded for the final time, the dead frog was found outside of the burrow.

Effects of Clearcuts and Controlled Burns.—Between 30 March and 2 April 1994, the private land 200 m north of Glen's Pond (then owned by IP) was clearcut, roller-chopped, and bedded for pine trees with heavy machinery. No frogs with transmitters were observed entering the

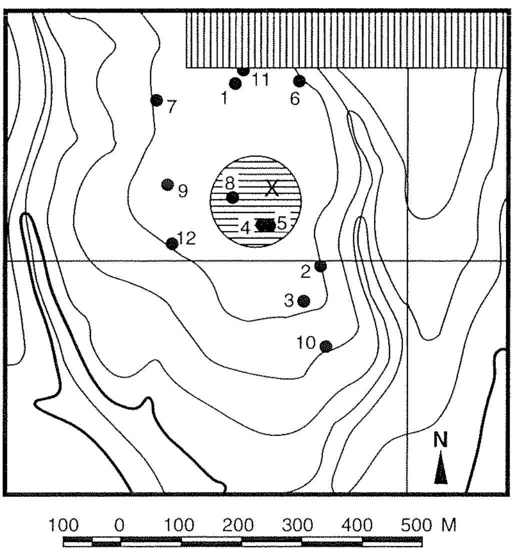

FIG. 1. Final localities of radio-tracked gopher frogs (numbered dots) relative to the area enclosed by the drift fence (horizontally hatched area), pond center (X), adjacent private land (vertically hatched area), and USDA Forest Service lands (unhatched area).

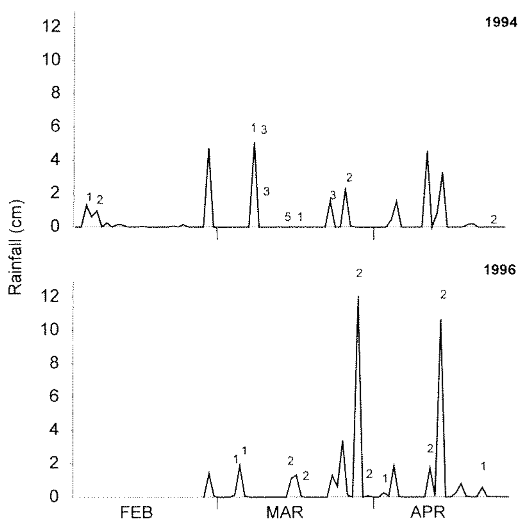

FIG. 2. Amount of rain (cm) and movements of telemetered gopher frogs throughout the study period. Number of frogs moving on a given day represented by numbers along the rainfall line.

clearcut, but of the frogs leaving the immediate vicinity of the pond, four moved toward this general area, three of which moved quite close to the clearcut (Fig. 1). In 1994, two individuals (#1 and #6) were tracked to final positions 10 m and 30 m from this area. In 1996, one frog (#11) moved twice (during two separate migration periods) to the boundary separating the U.S. Department of Agriculture Forest Service (FS) and IP property and took residence in an abandoned mammal burrow literally under the boundary fence (Fig. 1). This suggests that some frogs might have moved farther north had the IP land not been clearcut at the time.

Because suitable habitat for gopher frogs and other species in this longleaf pine ecosystem is maintained by periodic fire, a growing season prescribed burn of the entire study area was conducted by the FS on 26 April 1994, during which time three frogs had functional transmitters attached. All three frogs were active after the burn, and two postburn movements were recorded for each of two frogs. The third frog was not recaptured but was seen at a burrow entrance following the burn. Thus, as might be expected for frogs that occur in a fire-dependent habitat, there was no evidence that mortality resulted from the burn.

Behavioral Observations.—After movement to their upland refuges, most gopher frogs did not remain underground but were often seen outside of their burrows throughout the study. Distinctive resting areas were observed outside of each frog's burrow, consisting of soil cleared of vegetation and smoothed by the frog's constant use. In 1994, the activity of frogs outside their burrows was not closely monitored, although individual frogs were often observed in the open. In 1996, all frogs (except #12) were commonly seen basking in direct sunlight outside their respective burrows.

Although no negative effects of the transmitters were found in 1994, in 1996 three frogs were found with skin abrasions 21–26 days following release. When abrasions were found, the transmitters were removed, and frogs were monitored in the field. All frogs had healed when recaptured 8–14 days following transmitter removal and were seen outside of their burrows 8–46 days later. No further attempts at telemetry were made.

Discussion

Movement and Activity Patterns.—All postbreeding movements of gopher frogs occurred within 300 m of Glen's Pond, and distances moved were similar between years (Table 1). In both years, most movements were associated with rainfall events, an association seen in other anurans (e.g., Pechmann and Semlitsch, 1986). Our maximum distance is much less than has been observed for individual gopher frogs in Florida (1.6 and 2.0 km; Carr, 1940; Franz et al., 1988). These differences have at least two explanations: (1) observations on gopher frogs in Florida represented unusually long movements; and (2) gopher frogs in Florida generally have longer dispersal distances than gopher frogs in Mississippi. We lack data to sufficiently test these hypotheses, although recent studies by B. Blihovde (pers. comm.) suggest that long-distance movements (> 1 km) are rare in gopher frogs in central Florida.

We achieved our original goals by sampling postbreeding migrations, but caution must be taken in applying these data to maximum movement distances or total habitat used throughout the year. Sinsch (1990) explained the potential use of three "spatial units" (breeding site, nutrition site, and hibernation site) in frogs throughout a year. Briefly, after breeding, many anurans migrate from the pond to an area to feed and may subsequently migrate to a different area for hibernation. Gopher frogs breed during the winter; thus, they do not hibernate but do have periods of inactivity. We are uncertain to what extent *R. sevosa* uses different spatial units during periods beyond our study. A year-round examination of migratory behavior would be required for such data. Some time after removal of transmitters (1–46 days), frogs were no longer found perched outside of their burrows nor were the characteristic worn areas near the burrows seen. This indicates either that the frogs remained at these burrows underground or that they moved to another site, as is known for common toads, *Bufo bufo* (Sinsch, 1990).

Effects of Habitat Alteration.—In areas such as national forests, where timber management practices are implemented, an understanding of habitat use during both breeding and nonbreeding periods is essential. Forestry practices, such as the removal of trees and controlled burning, are known to have detrimental effects on amphibians but in some cases may be necessary for their survival in human-altered habitats (Waldick, 1997, and references therein). Knowledge of the behavior of the species allows management practices to be performed when the frogs are least likely to be affected. Two major habitat disturbances occurred during the study that may have affected gopher frogs: clearcutting in an adjacent habitat and controlled burning in the immediate vicinity of the pond. We found no short-term impact of prescribed burning on gopher frogs. All three individuals monitored during the burn survived with no apparent harm and resumed normal movements within 1–2 days. However, we cannot determine whether the burn may have impacted foraging success (either positively or negatively) or whether there were any long-term effects. Also, given the low sample size of frogs at the burn site, we cannot generalize from our results. Driscoll and Roberts (1997) found more extensive mortality from burns in *Geocrinia lutea* in Australia.

Our data suggest that at least some frog movements were affected by the clearcut. No telemetered frogs entered the clearcut, although some moved to areas along the boundary between the FS land and the clearcut (see Fig. 1). We strongly suspect that gopher frogs may have used the clearcut area prior to habitat alteration in 1994, given that (1) the clearcut is well within the radius of maximum dispersal distances from the pond (i.e., < 299 m), (2) one frog twice moved to the very edge of the clearcut, and (3) there were gopher tortoise burrows in this area before the habitat was clearcut and bedded (gopher frogs are reported to use gopher tortoise burrows extensively in Florida; Franz, 1986; B. Bilhovde, pers. comm.). Clearcuts are known to strongly influence the abundance of salamanders (e.g., Petranka et al., 1993); however, additional data on impacts of clearcuts on anurans is a major management need.

Conservation Implications.—Protection of the immediate vicinity of wetlands without consideration of the adjacent terrestrial habitat (as is often the case when federal statutes regulate this protection) is insufficient to maintain many wetland species (Burke and Gibbons, 1995; Dodd, 1996; Dodd and Cade, 1998). Because anurans that breed in temporary wetlands spend much of the year in terrestrial habitats, a buffer zone (as recommended by Burke and Gibbons, 1995; Dodd and Cade, 1998; Semlitsch, 1998) at least completely encompassing the nonbreeding season habitat is essential for their protection. The size of such buffer zones depends on several factors, notably the degree of fragmentation and the mobility of the species under consideration. The direct effects of disturbance to used habitat (e.g., loss of microhabitat; prey availability; change in hydroperiod) may be obvious, but alteration of the adjacent habitat must also be considered. If the habitat adjacent to the buffer zone is altered (e.g., clearcut or developed), organisms within the now fragmented habitat are potentially exposed to changes in microclimate such as wider fluctuations and changes in mean humidity, litter moisture, solar radiation, and temperature (i.e., edge effects; Saunders et al., 1991; Matlack, 1993; Murcia, 1995).

Management of the Mississippi Population.—Although gopher frogs at Glen's Pond moved fairly short distances (all < 299 m), three factors argue for a much larger buffer zone. First, the distances we found in our study may have been truncated by the presence of the clearcut to the north of our study site. Second, the private land 200 m north of Glen's Pond is being currently developed as a retirement community, which means that these frogs may be exposed to human-induced stresses such as fertilizer runoff and recreational activities. Thus, an additional buffer is required to lessen edge effects (Murcia, 1995). Third, two other ponds in the vicinity of Glen's Pond appear to be suitable breeding sites but are not currently being used by gopher frogs. These ponds (Reserve Pond and Pony Ranch Pond, 1.0 and 1.6 km from Glen's Pond, respectively) need to be included in a single buffer zone that would increase the likelihood of (re)colonization of these sites. Our recommendation is for a terrestrial buffer zone for each pond of 1000 m, which encompasses the nonbreeding season habitat and an additional buffer to reduce edge effects (Fig. 3). These buffer zones would also create corridors between the three ponds that are at least 800 m from the edge of altered habitats.

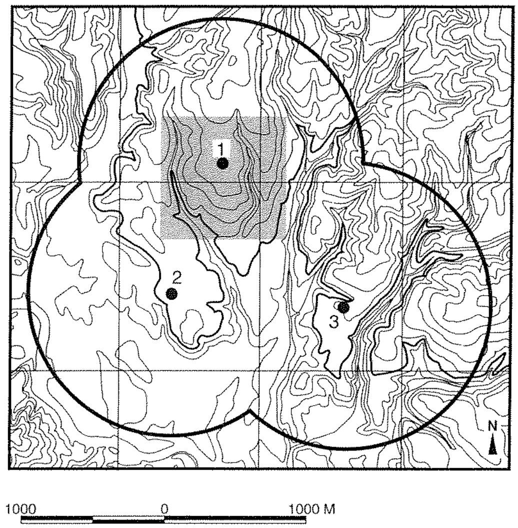

FIG. 3. Proposed 1000-m terrestrial buffer zones for Glen's Pond (1), Secondary Pond (2), and Pony Ranch Pond (3). The inset box around Glen's Pond (1) indicates the area depicted in Figure 1.

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